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Summary

Back disorders have long been recognized as a serious problem within the military aviation community and a possible threat to mission accomplishment. The purpose of the present study was to determine the extent to which type of aircraft flown is associated with diagnosed back problems, and to examine differences in the prevalence of back disorders between pilots and aircrew. A case-control study was conducted in which active-duty pilots and aircrew members with a diagnosed back disorder on their most recent physical exam between 1991 and 1993 were compared with pilots and aircrew without such diagnoses. Data were obtained from the automated physical examination records maintained by the Naval Aerospace and Operational Medical Institute for all naval aviation personnel. Results showed that aircrew members have a higher risk of diagnosed back problems than pilots for both helicopters and fixed-wing aircraft. The study revealed that flight engineers have a higher risk of diagnosed back problems than other aircrew members. Among pilots, no association was found between type of aircraft and diagnosed back problems.

Keywords: Navy, aviation, pilots, aviators, aircrew, back problems, fixed-wing, helicopter, aircraft, age.

In a recent health promotion survey, approximately half of the active-duty Navy sample reported some type of back problem in their lifetime (33). The Navy has conducted research and implemented programs to attempt to reduce back problems within its population (4,18,19,32); indeed, back injury prevention is one of the seven major elements of the Navy's Health Promotion Program, as directed by the Department of the Navy (5). Prevention has been critical in dealing with back disorders in both military (32) and civilian (27,28) populations, and it is facilitated by identifying risk factors or predictors of back problems (32). Such predictors are often work-related variables, such as type of job performed or tools utilized in job performance (28,32).

Due to the nature of their work, pilots and aircrew are held to stringent physical readiness standards in order to be considered qualified for flight. While many conditions may impact ability to perform flight duties, problems involving the back are serious because of the many microtraumas incurred by the spine during flight. Certain types of back problems can be greatly exacerbated by flight conditions and can, in the extreme, lead to disability (23). Less severe back problems may be an unacceptable distraction from concentration needed to perform duties during flight, or they can inhibit the mobility needed for flying and performing flight-related duties. According to the Naval Aerospace and Operational Medical Institute, in-flight back pain occurs in 13% of pilots, with a greater reported incidence for helicopter pilots (23). Auffret and Viellefond reported that helicopter pilots were twice as likely as the general population to have back problems involving decreased mobility of the spine (7). They postulate that this is due to the repeated exposure to vibration helicopter pilots experience. While pain alone is sufficient distraction to decrease performance, it could also be an indicator of other more serious back

problems. Conditions that may lead to minor performance problems in a more traditional work place could have catastrophic consequences if they impeded an aviator's ability to complete actions critical to flight.

Most aviator back problems not resulting from ejection from aircraft or crash impact are attributed to three factors: poor body positioning in the aircraft, vibration, and high G forces. Preexisting conditions may also contribute to the effects of these factors (1). The posture and overall body positioning of pilots is a common issue that has been examined as a cause of back problems, particularly in helicopter pilots. Helicopter aviators often must maintain leaning positions to manage their controls, and, in many cases, do so for extended periods of time. While deleterious posture alone may only cause back discomfort, in conjunction with the effects of vibration and acceleration, it increases the likelihood of damage (7).

Thoracic fractures and herniation of the lumbar disks in aviators have been attributed to the effects of vibration (7). Vibrational forces are distinguished by their frequency, amplitude, and velocity, which at different levels can have various effects. Auffret and Viellefond noted that the frequencies at which the human body has the least amount of tolerance are those at which most of the vibrations in aviation occur (7). Vibrations are most common at such levels in helicopters.

G-forces are most commonly cited as potential causes for back problems in high-performance aircraft. G-forces are forces that counteract the physiological acceleration of the body and have several components that moderate their impact on the aviator (7). These include "the axis in which the forces are applied, the magnitude of the accelerations, the time for which the accelerations are applied and their rate of onset or suddenness" (7). Their impact on the pilot

includes compressing and jolting the spinal column. The effects of G-forces have been linked to lesions in the ligaments around the vertebrae and to the manifestation of latent thoracic and lumbar arthritis (7). Since the intensity and abruptness of the accelerations involved varies with aircraft and types of maneuvers, different aircraft types may have different levels of G forces generally associated with them. This would imply the potential for different types and levels of severity of back problems. Each of the above factors has differential impact on the body, depending upon the type of aircraft flown. They are present in varying combinations in most of the aircraft types flown in the U.S. Navy.

In addition to the previously mentioned work-related variables, back problems have been found to vary by demographic variables, such as age, gender, and ethnicity (7). For example, age has been found to have a positive linear relationship to some types of back problems in male subjects, suggesting that gender and age could be potential predictors of risk (16). By identifying risk factors or predictors of back problems including work-related variables, such as aircraft and type of job performed, and demographic variables, such as age and gender, prevention efforts could be more effectively targeted.

The study of aviators and back problems in the literature over the past decade has tended to focus on the problems experienced specifically by helicopter pilots, or on spinal injuries sustained due to accidents in both helicopters and fixed-wing aircraft (3,9,10,25-27,30). When addressing the topic of aviation-related spinal problems in pilots of various fixed-wing types of aircraft, neck problems were often the focus (6,11,21). Whitton, however, did note that spinal disorders causing back pain were more likely to occur in fighter pilots than in other types of pilots

(31). Remes attributed this to increased pressure on the spine due to the position in which fighter pilots must work and the hours they must spend in that position (24). Aviation life support equipment that fighter pilots must use has not been ruled out as a contributing factor. A 1986 study, which compared back pain in fighter pilots, transport pilots, and helicopter pilots, found that fighter pilots had significantly more chronic pain, longer lasting pain, pain requiring bed rest, and pain radiating to the leg (8). The study also found that the pain reported by helicopter pilots was more likely to occur immediately after flight, while that of fighter pilots tended to occur at other times.

Aircrew also are susceptible to the external conditions that can harm pilots. Being in the same aircraft, they are expected to perform their duties under similar conditions of vibration and deleterious posture, although the posture often varies from that of the pilot. Aircrew members often are expected to look at screens or strain to use other equipment critical to their job tasks. As a population, they also are at risk for back problems, and, in some cases, where lifting is a part of their job, they may even be at a greater risk than the pilot of the aircraft. Often studies analyzing back problems will group aircrew members with pilots or will focus solely upon the pilot. This study will examine diagnosed back problems in both groups.

A case-control study of aircraft type and diagnosed back problems may illuminate which pilots are at risk for back problems, and help to better target prevention efforts. A few studies have examined general health conditions of aviators in the U.S. Navy by aircraft type (12-15). Hoiberg found a significant relationship between aircraft type and 9 of 14 health problems in her 1984 study (12). The Hoiberg study presented "diseases of the back" as a whole and did not

include fractures and strains of the back, thus precluding an examination of the range of potential back problems.

The primary purpose of this study was to determine the prevalence of a wide range of diagnosed back problems among pilots and flight crew, and to examine the extent to which the type of aircraft was associated with back problems. The primary hypotheses are (1) that the risk of back problems will vary with type of aircraft for both pilots and aircrew; (2) that aircrew members will have a significantly greater likelihood of diagnosed back problems than pilots; and (3) that specific back disorders will vary with job category, defined as pilot or aircrew.

MATERIALS AND METHODS

Study population: Pilots included all U.S. Navy pilots and flight officers with occupational codes indicating an Aviation Warfare specialty. Classes of U.S. Navy pilots were determined using only Service Group 1 (SG1), SG2, SG3, and Naval Flight Officer (NFO) classifications (N=5095), with students and candidates excluded. These officer standard classifications are distinguished by their physical requirements, particularly vision standards, with SG1 having the most stringent standards (23).

Aircrew included all enlisted aircrew members classified as designated for fixed-wing, ejection seat, flight engineer, airborne sonar operator, flight communications operator, helicopter aircrew, helicopter rescue aircrew, cryptology, and search and rescue duties (N=2580). A cross check was performed with the duty status of all pilots and aircrew selected to verify that they actually were working in their current designation; otherwise, they were eliminated from the sample. Only those pilots and aircrew members who were active duty, reserves, or ready reserves

were included in the sample (N=7675).

Cases were comprised of those subjects with back problems diagnosed during their physical exam, with controls consisting of all other U.S. Navy pilots and aircrew without diagnosed back problems. Diagnosed back problems were defined using the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) and included all codes of injury or disease specifically related to the back, as shown in Table I.

TABLE I

Procedure: The Naval Aerospace and Operational Medical Institute's (NAMI) automated physical examination records, maintained on all naval aviation personnel, were the source of the data used in this study. This computerized database system, the Aviation Medical Data Retrieval System (AMDRS) incorporates a double data entry reliability checking scheme and has been described in detail elsewhere (2,17). Data included the most current physical examinations from January 1991 to December 1993 for all subjects.

Variables included for comparison of both pilots and aircrew were age, gender, ethnicity, and aircraft group (fixed-wing or helicopter). Age was divided into a trichotomy of under 30, 30-40, and over 40 years of age. To make job category comparisons between aircrew members and pilots, the designations for aircrew and aircraft type for pilots were collapsed to form overall helicopter and fixed-wing aircraft groups. The helicopter group contained all pilots with helicopters as primary aircraft types and all aircrew members whose designation was helicopter or helicopter search and rescue. The fixed-wing group contained all pilots with propeller or jet

Table I. PERCENT DISTRIBUTION OF TYPE OF BACK DISORDER BY JOB CATEGORY, NAVAL AVIATION PERSONNEL, 1991-1993.

	Pilots		Aircrew		Total	
Type of back disorder	N	%	N	%	N	%
Intervertebral disc disorders *	40	46.5	36	42.4	76	44.4
Other dorsopathies †	15	17.5	28	32.9	43	25.1
Curvature of the spine ‡	18	20.9	8	9.4	26	15.2
Other injury or disease of the back §	13	15.1	13	15.3	26	15.2
Total	86	100.0	85	100.0	171	100.0

*ICD-9 codes: 722.10-722.39, 722.50-722.70, 722.82-722.90, 722.92-722.99

†ICD-9 codes: 720-720.99, 721.2-721.99, 724.0-724.99

‡ICD-9 codes: 737.1-737.99

§ICD-9 codes: 733.0-733.09, 738.4-738.59, 739.20-739.49, 756.1-756.19, 781.9, 805.2- 805.79, 806.2-806.79, 839.20-839.49, 846.0-846.9, 847.1-847.9, 926.11, 952.1-952.99, 953.1-953.8

primary aircraft types and all aircrew members whose designation was fixed-wing, ejection seat, or flight engineer. Aircrew designations for which a sole aircraft group could not be distinguished were excluded from the analysis between pilots and aircrew, leaving 93 aircrew members (such as sonar operators, flight communications operators, and cryptologists) who were not included in the comparison.

One variable available solely for pilots was primary aircraft type, and it included five categories: Attack and Fighter Jet, Other Jet, Propeller Antisubmarine Warfare, Other Propeller, and Helicopters. One variable available solely for the aircrew was job designation, which was defined by aircraft type for those designated for general aircrew duties (fixed-wing, ejection, helicopter), and by aircrew specialty for those who were designated for special duties, which they were qualified to perform within any applicable type of aircraft (including airborne sonar operators, flight communications operators, cryptologists, and those with standard search and rescue designation). Cumulative flight hours at the time of the exam were unavailable for all subjects; however, for subjects with flight hours available, age and flight hours were strongly correlated at $r=0.62$ ($p<0.001$). Therefore, age may be considered a proxy for number of flight hours.

Statistical analyses were conducted using the SAS statistical package. The procedure FREQ was used to produce descriptive statistics and the chi-square test of association. Crude and adjusted odds ratios (ORs) with 95% confidence intervals (CIs) were calculated to determine the risk of back disorders within the total sample, and separately within pilots and aircrew. Cochran-Mantel-Haenszel tests were conducted to examine significant relationships between job

category and diagnosed back disorder by age, gender, and ethnicity.

RESULTS

A total of 171 of the 7675 subjects, 2.2% of the sample, were diagnosed with some type of back problem. The most commonly reported back disorder was intervertebral disc disorders (44.4%), followed by other dorsopathies (25.1%), and curvature of the spine (15.2%). Table I shows the frequency distribution of each diagnosis by job category. Among the aircrew, intervertebral disc disorders were most common, followed by other dorsopathies, while among the pilots, intervertebral disc disorders were most common, followed by curvature of the spine (X^2_3=7.98, p=0.046).

No association was observed between back problems and gender or ethnicity for either pilots or aircrew (Table II). The only factor with a significant relationship to back problems was age group, with pilots over the age of 40 having a greater proportion of reported back problems than younger pilots. Younger aircrew members were also less likely to have diagnosed back problems, and those aircrew members with back problems were significantly younger than pilots with back problems (mean $age_{aircrew}$=33.0 years, SD=7.69; mean age_{pilots}=39.6, SD=7.67, T_1=5.56, p=0.0001). Analyses showed that age and specific diagnoses also were significantly related to each other with disc disorders more common among older personnel (X^2_6=15.9, p=0.015).

TABLE II

As shown in Table III, only flight engineers were more likely to have a diagnosed problem when compared with those designated for other aircrew jobs. Table IV shows the distribution

Table II. FREQUENCY DISTRIBUTION OF DEMOGRAPHIC VARIABLES IN NAVAL AVIATION PERSONNEL WITH AND WITHOUT DIAGNOSED BACK DISORDERS, 1991-1993.

	Pilots				**Aircrew**				**Total Sample**			
	With Back Disorders		Without Back Disorders		With Back Disorders		Without Back Disorders		With Back Disorders		Without Back Disorders	
	N	%	N	%	N	%	N	%	N	%	N	%
Gender												
Male	85	98.8	4933	98.5	83	97.6	2398	96.1	168	98.3	7331	97.7
Female	1	1.2	76	1.5	2	2.4	97	3.9	3	1.7	173	2.3
	X^2_1=0.07, p=0.789				X^2_1=0.53, p=0.469				X^2_1=0.23, p=0.634			
Ethnicity												
White	86	100.0	4919	98.2	83	97.6	2390	95.9	169	98.8	7309	97.4
Black	0	0.0	55	1.1	1	1.2	77	3.1	1	0.6	132	1.8
Other	0	0.0	33	0.7	1	1.2	26	1.0	1	0.6	59	0.8
	X^2_2=1.54, p=0.463				X^2_2= 1.03, p=0.596				X^2_2=1.45, p=0.484			
Age Group												
<30	10	11.6	1130	22.6	28	32.9	1269	50.9	38	22.2	2399	32.0
30-40	29	33.7	2439	48.7	42	49.4	960	38.5	71	41.5	3399	45.3
>40	47	54.7	1440	28.7	15	17.7	266	10.6	62	36.3	1706	22.7
	X^2_2=27.87, p<0.001				X^2_2=11.47, p=0.003				X^2_2=18.80, p<0.001			

of aircraft types for pilots with and without back problems. No significant difference between pilots with back problems and those without back problems was found for any aircraft type.

TABLES III AND IV

In examining the relationship between diagnosed back disorders and aircraft group, no significant difference in risk was found (OR=0.70, 95% CI=0.45, 1.08). However, when aircrew are compared with pilots, aircrew members had significantly more diagnosed back problems than pilots within both helicopter and fixed-wing aircraft groups (Table V). Adjusting for age, helicopter aircrew members had more than three times the risk for back problems compared with helicopter pilots. Among fixed-wing aircraft personnel, aircrew had more than two times the risk as pilots. As tests for homogeneity revealed significant differences among the odds ratios in the fixed-wing aircraft group (X^2_2=7.3, p=0.026), individual odds ratios for each category were calculated (Table VI).

TABLES V AND VI

Among fixed-wing personnel under 30 years of age, the risk of diagnosed back problems in aircrew was three times that compared with pilots, and among those between the ages of 30 and 40, the risk of diagnosed problems in aircrew members was almost four times that of pilots.

Table III. ODDS RATIOS AND 95% CONFIDENCE INTERVALS ACCORDING TO JOB DESIGNATION, NAVAL AIRCREW WITH AND WITHOUT DIAGNOSED BACK DISORDERS, 1991-1993.

	With Back Disorders		Without Back Disorders		Odds Ratio	95% Confidence Interval
Job Designation**	N	%	N	%		
Fixed-wing	54	63.5	1691	67.8	0.83	(0.53, 1.30)
Ejection Seat	1	1.2	9	0.4	3.29	(0.46, 23.36)
Flight Engineer	17	20.0	227	9.1	2.50*	(1.47, 4.25)
Helicopter	5	5.9	162	6.5	0.90	(0.36, 2.25)
Helicopter Search and Rescue	8	9.4	323	12.9	0.70	(0.34, 1.46)
Airborne Sonar Operator	0	0.0	17	0.7	Not Applicable	
Flight Communications Operator	0	0.0	6	0.2	Not Applicable	
Cryptology	0	0.0	22	0.9	Not Applicable	
Search and Rescue	0	0.0	38	1.5	Not Applicable	
Total	85	100.0	2495	100.0		

*Odds ratio significant at 0.05.
**mutually exclusive categories, coded by NAMI

Table IV. ODDS RATIOS AND 95% CONFIDENCE INTERVALS ACCORDING TO AIRCRAFT TYPE, NAVAL PILOTS WITH AND WITHOUT DIAGNOSED BACK DISORDERS, 1991-1993.

	Back Disorders		Without Back Disorders		Odds Ratio	95% Confidence Interval
Aircraft Type	N	%	N	%		
Attack and Fighter Jet	25	29.1	1203	24.0	1.30	(0.81, 2.07)
Other Jet	9	10.6	644	12.9	0.79	(0.40, 1.60)
Propeller Antisubmarine Warfare	32	37.2	1639	32.7	1.22	(0.78, 1.89)
Other Propeller	9	10.5	596	11.9	0.87	(0.43, 1.73)
Helicopter	11	12.8	927	18.5	0.65	(0.34, 1.22)
TOTAL	86	100.0	5009	100.0		

Table V. UNADJUSTED AND AGE-ADJUSTED ODDS RATIOS (OR) AND 95% CONFIDENCE INTERVALS (CI) FOR THE EFFECT OF JOB CATEGORY ON DIAGNOSED BACK DISORDERS, BY AIRCRAFT GROUP, 1991-1993.

	Helicopter				**Fixed-wing**				**Total**			
	With Back Disorders		Without Back Disorders		With Back Disorders		Without Back Disorders		With Back Disorders		Without Back Disorders	
Job Category	N	%	N	%	N	%	N	%	N	%	N	%
Aircrew	13	2.6	485	97.4	71	3.6	1918	96.4	84	3.4	2403	96.6
Pilot	11	1.2	927	98.8	75	1.8	4082	98.2	86	1.7	5009	98.3
Total	24		1412		146		6000		170		7412	
Test statistic	X^2_1=4.1, p=0.043				X^2_1=18.1, p<0.001				X^2_1=21.8, p<0.001			
Unadjusted OR(95% CI)	2.26 (1.02 - 4.98)				2.02 (1.46 - 2.78)				2.04 (1.51 - 2.75)			
Age-adjusted OR (95% CI)	3.55 (1.66 - 7.57)				2.59 (1.83 - 3.67)*				2.73 (1.99 - 3.76)			

* Test of homogeneity among age groups significant at .05.

Table VI. ODDS RATIOS AND 95% CONFIDENCE INTERVALS FOR DIAGNOSED BACK PROBLEMS IN AIRCREW MEMBERS COMPARED WITH PILOTS BY AGE AND AIRCRAFT GROUP, 1991-1993.

	Helicopter		**Fixed**		**Total Sample**	
	Odds Ratio	95% Confidence Interval	Odds Ratio	95% Confidence Interval	Odds Ratio	95% Confidence Interval
Age Group						
<30	1.36	(0.28, 8.16)	2.96	(1.38, 6.36)	2.62	(1.30, 5.28)
30-40	3.69	(1.11, 12.22)	3.81	(2.35, 6.19)	3.78	(2.42, 5.92)
>40	8.73	(2.71, 28.17)	1.18	(0.58, 2.38)	1.64	(0.89, 3.00)
Unadjusted	2.26	(1.02, 4.98)	2.02	(1.46, 2.78)	2.04	(1.51, 2.75)
Age-adjusted	3.55	(1.66, 7.57)	2.59	(1.83, 3.67)	2.73	(1.99, 3.76)
Homogeniety of odds ratios	X^2_2=2.91, p=0.233		X^2_2=7.296, p=0.026		X^2_2=4.546, p=0.103	

Note: O=pilot, 1=aircrew; 0=no back problem, 1= back problem.

In contrast, fixed-wing aircrew over 40 years of age were not at higher risk for back problems in comparison with pilots.

DISCUSSION

Contrary to expectations, the first hypothesis that risk of back problems would vary with type of aircraft for both pilots and aircrew could not be supported. However, the increased prevalence of diagnosed back problems among aircrew members supported the second hypothesis. The finding that aircrew members had significantly more back problems than pilots for both helicopter and fixed-wing aircraft may be because aircrew members are more likely to carry heavy equipment than pilots, to perform work more likely to cause injury during flight than work performed by pilots, or because aircrew members have a greater tendency to report problems to a flight surgeon during a physical exam than pilots do. Each of these areas may be contributing to the differential patterns detected for aircrew and pilots, and, therefore, should be explored in further research. The differences in the frequencies of diagnosed back problems between the two groups also may be an indication of different tasks involved in their jobs that are contributing to their specific back problems. While both groups were most likely to have intervertebral disc disorders if back problems were present, the aircrew members' greater tendency toward unspecified disorders of the back and the pilots' toward spinal curvature may represent the effects of different factors in their work environments. Since pilots, as a group, are older than aircrew members, age could be a contributing factor, but subjects with spinal curvature, as a whole, were not older than those with other back problems. Preexisting conditions of spinal curvature cannot be ruled out; they are still of importance since they can

make both pilots and aircrew members more susceptible to other back problems. The possibility also exists that those who are selected as pilots are of such physical conditioning that they are less susceptible to the back problems associated with the forces involved in flying. Other possibilities may be that pilots have an advantage of a protective anticipatory musculature by virtue of their "being in the driver's seat", or that certain high performance aircraft that do not carry aircrew confer less risk of back disorder. Further, given the strong association between age and cumulative flight hours, the finding that pilots with diagnosed back disorders were older than pilots without may point to time-dependent effects in back disorder risks. Caution should be noted, however, in that only longitudinal studies will be able to determine the direction of such effects, such as whether back problems are the result of a greater number of flight hours or if pilots cut back on their flight time due to back disorders. Future research that would shed more light on back problems directly attributed to flying should include comparisons of entry flight physicals with later physical exams to eliminate the effect of preexisting conditions. This also may indicate if some preexisting conditions are more likely to increase prevalence of back problems with only certain types of aircraft or under specific flying conditions.

This study proved to be more valuable in illuminating back problems in aircrew than in the pilots, even though more specific information about aircraft type was available for pilots than for aircrew. Flight engineers were found to have a significantly increased likelihood of back problems when compared with all other aircrew members, which could be attributed to the specific type of function they perform. Flight duties for flight engineers include monitoring engine and hydraulic performance while positioned in the aircraft between the pilot and copilot. Ground duties include,

but are not limited to, inspecting the aircraft, and servicing oil and fuel. It is possible that duties performed while not in flight may contribute substantially to the increased prevalence of back problems in flight engineers. Factors that should be examined to determine the nature of flight engineers' increased risk of back problems include those that could differentiate their tasks from those of other aircrew members, such as the type of equipment they use and the position in which they use it.

An important strength of this study is its population-based approach in which all aviator and aircrew personnel who had a physical exam between 1991 and 1993 were eligible to be included. This population included all available women; however, the small number of female pilots and aircrew members did not allow for a focus on potential gender differences within the same aircraft type or job designation. While few significant results specifically addressed back problems in pilots in this study, our findings do not completely rule out the possibility that aircraft type has some association with back problems in this group. The greatest limitation of the study was the reliance upon pilots' self reports of symptoms to the examining physician that are necessary for the medical diagnosis of back problems. Because reporting back problems or injury to a health care professional may result in being grounded, pilots may be very reluctant to disclose their problems. While grounding and loss of flight-related benefits also affect aircrew members, they may have less of an effect on underreporting since grounding has less impact on career progression in the less competitive aircrew jobs. That is, pilots could be less inclined to express symptoms during an examination than aircrew members due to a perceived greater loss of benefits and status in the event of grounding. Indeed, anecdotal evidence suggests some pilots visit

chiropractors for their back problems to avoid having the need for treatment noted on their military medical record. Aviation psychology may also be an issue involved in underreporting. After enduring the rigorous processes involved in becoming a pilot, a tendency to view oneself as invincible, invulnerable, and capable of handling all situations can develop (22). This type of attitude, which saturates a pilot's career, might also lead him/her to be less inclined than other groups in the Navy to tolerate the possibility of grounding for medical reasons and, conversely, more inclined to tolerate pain and physical damage. The competitive edge may make the threat of grounding all the more severe and less tolerable.

In this review of physical examinations from 1991 to 1993, less than 2% of pilots reported any type of symptomology that led to the diagnosis of a back problem by their physician. Due to the impact of maintaining flight hours and flight status, pilots of all types of aircraft are likely to underreport medical problems. Degrees of underreporting may vary based upon the command, the relationship with the flight surgeon, and the individual's fears about the impact of down-time on his/her career (20). A suggestion for further research would be an attempt to approximate the degree of underreporting, which could then be factored into studies examining diagnosed back problems as well as other medical issues affecting aviators. Strategies to reduce the prevalence of underreporting also should be examined in future research, as should the relationship between underreporting of health issues and accidents, as well as other performance issues.

Another area for future research is the relationship between the strength of the back muscles and their influence on the spine's susceptibility to damage. This area may have some predictive validity and should be examined as a preventive measure for both helicopter and fixed-

wing aircraft pilots and aircrew. A combined effort by the U.S. Air Force and U.S. Navy has resulted in the creation of a physical fitness program specifically designed for the purpose of muscle strengthening to increase tolerance to G forces (34). The physical fitness measures in the program, however, have limited emphasis on the strengthening of the muscles of the back. Similar programs for helicopter pilots and aircrew are now being examined and both types of fitness efforts should be strongly encouraged, since research has shown that four of the most commonly diagnosed back problems in the Navy would benefit from such programs (4). Delahaye, Auffret, Metges, Poirier, and Vettes suggested strategies designed to develop the lumbar region, including "postural and stretching exercises for the spine and exercise involving the abdominal, gluteal and dorsolumbar muscles" to increase the strength of the muscles protecting the spine (7). An examination of the implementation of such a program and further research into the impact of strengthening these muscles might provide some degree of prevention and control over back strain and problems normally experienced by pilots and aircrew. Since aircrew members have more diagnosed back problems, they would be a good group to target research that tests a muscle strengthening strategy. This also might be one of the areas where the flight surgeon could provide insights and suggestions about proper exercise techniques for the aircrew members to utilize on their own time. If these techniques prove to offer some substantial relief for the aircrew, pilots may follow suit as a preventative measure due to the seriousness of the consequences of grounding. Since most of the other factors implicated in current research are only correctable through ergonomic changes to the aircraft, this may be one of the more fruitful areas to concentrate on in examining risk and reduction of back problems.

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Back disorders have long been recognized as a serious problem within the military aviation community and a possible threat to mission accomplishment. The purpose of the present study was to determine the extent to which type of aircraft flown is associated with diagnosed back problems, and to examine differences in the prevalence of back disorders between pilots and aircrew. A case-control study was conducted in which active-duty pilots and aircrew members with a diagnosed back disorder on their most recent physical exam between 1991 and 1993 were compared with pilots and aircrew without such diagnoses. Data were obtained from the automated physical examination records maintained by the Naval Aerospace and Operational Medical Institute for all naval aviation personnel. Results showed that aircrew members have a higher risk of diagnosed back problems than pilots for both helicopters and fixed-wing aircraft. The study revealed that flight engineers have a higher risk of diagnosed back problems than other aircrew members. Among pilots, no association was found between type of aircraft and diagnosed back problems.

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